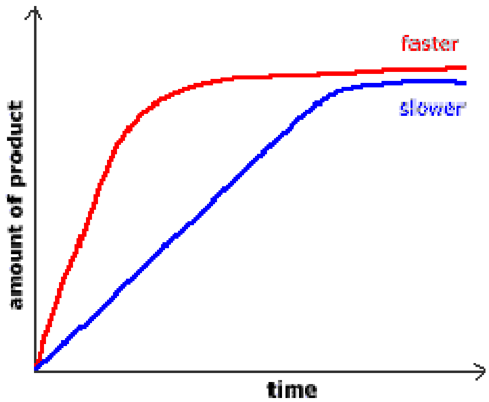
Reaction Rates

Key Concepts

- The rate of a chemical reaction is the speed with which reactants are converted to products. Two types of rates can be determined: average rate or instantaneous rate.

In general, **the average rate =** $\frac{\textit{change}\text{ in quantity}}{\text{change in time}}$, units could be mol/s , L/s , etc…



Plotting the points of quantity measured vs time produces a graph.
The initial slope of the graph provides you with the initial rate of reaction.
A fast reaction will have a steeper slope than a slower reaction. As products are formed, there are fewer reactant particles to react which means there will be fewer successful collisions, so, the reaction rate decreases.

If the reaction involves gases or solutions, then

the average rate = $\frac{\textit{change}\text{ in concentration}}{\text{change in time}}$, units are mol/L. s which is also expressed as mol.L^{-1}. s^{-1}.

To find the average rate of a reaction, determine the slope of the secant line connecting the points involved.

The **instantaneous rate** is the rate at a particular time. It can be found by drawing a tangent to touch the concentration-time curve at a given point and determining its slope.

Rates for different reactants and products are related by the coefficients in the balanced equation.

For the reaction : $2N_2O_5 \text{ ---> } 4NO_2 + O_2$

$$\frac{[\mathrm{N_2O_5}]}{\Delta \mathrm{t}} = 2\frac{[O_2]}{\Delta t} = \frac{2}{4} or \frac{1}{2}\frac{[NO_2]}{\Delta t}$$ by convention rates of reactions are positive.

Measuring Reaction Rates

How a reaction rate is measured depends on the nature of the reactants and products.

Some measurable quantities are:

- the volume of gas evolved per unit time
- the mass of solid formed per unit time
- the intensity of colour per unit time
- the change in pH per unit time
- the change in temperature per unit time
- the change in conductivity (ion production) per unit time

Every reaction has an activation energy which is the minimum energy required for a reaction to occur. The higher the activation energy the slower the reaction. Endothermic reactions are slower than exothermic reactions because they tend to have higher activations energies.

Collision Theory

Collision Theory is used to explain why chemical reactions occur at different rates. Collision Theory states that in order for a reaction to proceed, the reactant particles must collide. The more collisions there are per unit of time, the faster the reaction will be. However not all collisions are **effective collisions**!

For an effective collision, the reactant particles must:

a. collide with sufficient energy to break any bonds in the reactant particles. The activation energy is the minimum amount of energy the colliding reactant particles must have in order for products to form.
b. be in an orientation favourable for breaking those bonds.

Factors that affect reaction rates:

a. concentration of reactants
Increasing the concentration of reactants in solution increases the number of reactant particles which increases the number of collisions so the reaction rate increases.
Increasing the pressure of a gaseous reaction by adding more reactant gas particles increases the number of collisions so the reaction rate increases.
Increasing the pressure of a gaseous reaction by reducing the volume of the reaction vessel increases the number of collisions so the reaction rate increases.

b. Temperature (which is a measure of the kinetic energy of the particles)
Increasing the temperature of a reaction increases the kinetic energy of the particles which increases the number of collisions so the reaction rate increases.
Increasing the kinetic energy of reactant particles also means more of the reactant particles will have the minimum amount of energy required to form products (ie, activation energy) which leads to more successful collisions and therefore increases the reaction rate.
Increasing the temperature will increase the reaction rates of both endothermic and exothermic reactions.

If you plot the number of collisions in a substance at a given temperature against the kinetic energy of each collision, you get a curve known as Maxwell-Boltzmann distribution. The graph below shows that. Only the area after the dotted line represents the collisions with energy greater than the activation energy.

What happens to the graph when the temperature is increased?

c. particle size
Smaller reactant particles provide a greater surface area which increases the chances for particle collisions so the reaction rate increases.

d. presence of a catalyst
A catalyst lowers the activation energy for the reaction so more reactant particles will have the minimum amount of energy required to form products so the reaction rate increases.

e. rate of stirring
Stirring keeps reactant particles in motion increasing the chances of collision and increasing the rate of reaction.

f. Phase of the reactants
Homogeneous reactions (reactants are in the same state tend to be faster than heterogeneous reactions (where reactants are in different states. This is because the reactants will have a greater opportunity for colliding. The relative rates are:

Gases: fastest Liquid/solutions: fast solids: slow

Example

Consider this reaction: $Zn_{(s)} + 2HCl_{(aq)} \rightleftharpoons ZnCl_{2(aq)} + H_{2(g)}$

Condition	Affect on Rate	Explanation
Concentration	Increasing the concentration of HCl will increase the reation rate.	More HCl particles means there will be more collisions between HCl and Zn.
Temperature	Increasing temperature increases the reaction rate.	HCl particles will gain more kinetic energy increasing the number of collisions with Zn atoms. More Zn and HCl particles will have sufficient energy to react resulting in more successful collisions.
Particle Size	Reducing the size of Zn particles will increase the rate of reaction.	Reducing the size of the Zn particles increases the surface area available for reaction with HCl molecules resulting in more collisions.
Stirring Rate	Increasing the stirring rate of this mixture will increase the reaction rate.	Stirring will keep small Zn particles in suspension, increasing the surface area available for collisions, resulting in an increased reaction rate.